Development of a Customized Post Processor for Application of Universal Indexing Head on a Three Axis Vertical Machining Center

Chandranath.M[*], Mohan Naik.C[*], R. Suresh[**], S. Ravishankar[*a]

[*] Scientist, [**] Scientist Fellow, C-CADD, CSIR-National Aerospace Laboratories,

NWTC Road, Bangalore, India

[a] Corresponding Author

ABSTRACT

The machining of aerospace parts is a complex field that involves manufacturing of intricate components containing extensive closed wall machining requiring five axes machining centers. The non-availability of five axes machining centers and their high cost of operation necessitates manufacturing of such parts on a three axes machining center with the usage of sine-table fixtures, special formed tools or indexing head. This paper proposes a methodology for the usage of indexing head on a three axis vertical machining center with a customized post processor for a dedicated CNC controller combination to achieve closed wall machining, with reduced setup time and increased positional accuracy and rigid work holding methods.

The dedicated customized Post Processor has been developed for a three axes CNC machining center with three orthogonal linear axes (X, Y & Z) for an Indexing-head attachment with two rotary axes (A & C), to convert the machine into a positional five axes machining center for a specific controller, based on CAMPOST 17 software.

This paper examines in detail the technical issues concerning the development of a positional five axes post processor. This paper endeavors to explain the degree with which this customized post processor incorporates the advantages of the combined capabilities available in the machining center, the controller and the indexing head. The validation of this new post processor is carried out both on simulation software and by manufacturing a typical five axes component on a three axis machining centre.

Keywords:

Controller, Indexing head, Post processor, Angular head attachment, Simulation

1. Introduction

The machining of intricate closed walled parts with a three axis machining center requires a special work holding devices viz., sine table, special fixtures, special tools etc. The setting and positioning of the part on the machine will be a time consuming task in order to meet the required orientation and positional tolerances. This necessitated the application of higher axes machining centers for quick positioning with high accuracy and repeatability rate. The availability of five axis machining centers is limited and involves higher machining hourly rates. This paper proposes the development of a dedicated post processor for the usage of the Universal Indexing Head attachment for a three axes Vertical Machining Center to mitigate the problems mentioned above.

Angle head tools provide the means for complete, integrated machining. It is no longer necessary to repeatedly relocate the jobs for multiple setups, which means a considerable reduction in production costs, rationalization and increase in flexibility over the entire production process.

The usage of an Indexing attachment necessitates the development of a customized post processor which can integrate the Indexing head capabilities along with the three axes machining center features and its controller. The development of such a customized post processor requires a good understanding of the machine, controller and indexing head capabilities for its successful integration.

This paper is an effort in this direction to develop a dedicated customized post processor consisting of the controller specifications of FANUC Series 21i-MB® Controller with three axes Vertical machining center, using the CAMPOST® V17 [4] interactive post processor building software.

2. Development of the customized post processor

The development of the customized postprocessor involves understanding the specifications of the machine, its controller and the post processor building software, in this case CAMPOST® V17. It is necessary that all the machine and controller details are effectively built into this post processor generator. The post processor output is generated for a typical standard test case for which the CL data/APT source is available and is verified using machining simulation software. Based on this validation, the actual metal cutting operation on the specified machining center is undertaken and the manufactured part is subjected to inspection. The result of this inspection certifies the performance of the dedicated post processor.

2.1 Machining Center Specifications

A typical three axes Vertical Machining Center (VMC) is considered with three orthogonal linear axes (X, Y, Z). These machines are most widely used in manufacturing industries. The machine used for the development of the customized post processor is controlled by FANUC Series 21i-MB® controller. The X, Y and Z axes traverses are 1020 mm, 550 mm and 560 mm respectively. The rapid axis feedrate of X and Y axes are 40 m/min while for Z axis is 20m/min. This machining center has a tool storage capacity of 20 tools.

2.2 Indexing Head Specifications

2.2.1 Angle Head Attachment:

The Tilting-axis machining eccentric head is used as a five axis machine tool to machine the compound angle faces with inaccessible areas on a three axes machining zone.

It is directly mounted to the machine spindle, similar to fixing the tool on the CNC machine spindle. Its rotational movement is fixed at a compound angle in both of A and C rotational axis.

The customized postprocessor is designed to generate a CNC program at the tool tip, which follows the contour. The orientation of the tool axis is controlled by 'A' and 'C' axes angles which are set manually in the Indexing head attachment.

It is effectively used for positional five axes drilling and milling operations, which otherwise requires a sine table operation or costlier five axes machining center. The rigid and fast eccentric head is especially suitable for machining of aluminium components which are extensively used in aircraft part manufacturing.

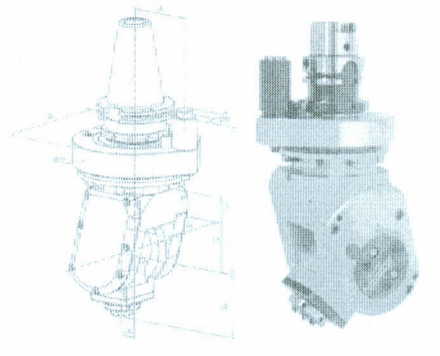

Fig 1: Mimetic® angle head with HSK63

2.2.2 Features:

The angle head spindle can run at high speeds up to 7,000 rpm and can withstand high torque of up to 30 Nm. This Angle head can be rotated through 0-360° w.r.t C axis using the six setscrews on the adjusting ring and can be rotated through +/-98° w.r.t A axis passing through 6 x 15° indexations for adjustable angle units. It consists of extremely precise bearing technology, high concentricity and high rigidity and can also be used for positional five axis for drilling, reaming, countersinking, threading and milling operations. Machining accuracies within +/-0.01mm can be achieved.

2.2.3 Pivot distance:

The pivot distance is the most crucial parameter in five axis machining. It is the distance between pivoting point and the tool tip. As the tool length used varies for different operations the distance between the pivot point and the spindle face (constant irrespective of the tool used) is taken as the pivot distance. In the present scenario there are two pivot offsets, i.e. the Y-offset which is the distance from rotary axis C to the rotary axis A which is 25.1mm and the Z-offset which is the distance from the face of the spindle to the rotary axis A and is 79mm as shown in Fig. 1.

2.3 Controller Specifications

The machining center is integrated with FANUC Series 21i-MB® controller. This controller is used on milling centers having up to 5 axes control and up to 4 axes simultaneous control. Its advanced features include Standard ISO canned cycles, Work coordinate system selection and Transformations options among other features.

2.4 Postprocessor Builder

The Postprocessor Builder is used to create a post processor, for a given Controller and Head attachment, to calculate motions needed on a specific CNC Machining Center to reproduce the CAM vector model using Tool axis vectors and XYZ coordinates from

APT file to give the NC file.

The postprocessor Builder used to develop the dedicated postprocessor is CAMPOST® V17. This interactive software can accommodate a wide variety of machine types having continuous path control. It essentially consists of two parts: QUEST and GENER.

QUEST is an interactive program that builds a database containing information about specific machine and its controller. GENER uses this database, along with the cutter location files generated by CAM system, to produce the final CNC control code for each particular machine.

The QUEST interactive program incorporates the following parameters such as general description in which the type of machine, program output requirements, positions available and display formats are taken into account. In this the machine type was chosen as Mill (Contour, Lathe, Mill…) with the machine configuration as VMC three-Axis XYZ Milling machine and with Rotary head attachment option enabled, which results in using the appropriate kinematics matrices from the database while post processing the APTSOURCE file. Also important is the type of control chosen i.e. FANUC Series 21i-MB®. The controller description deals with the information pertaining to the machine control such as major control codes, auxiliary codes, linear and circular interpolation codes as shown in Fig. 2.

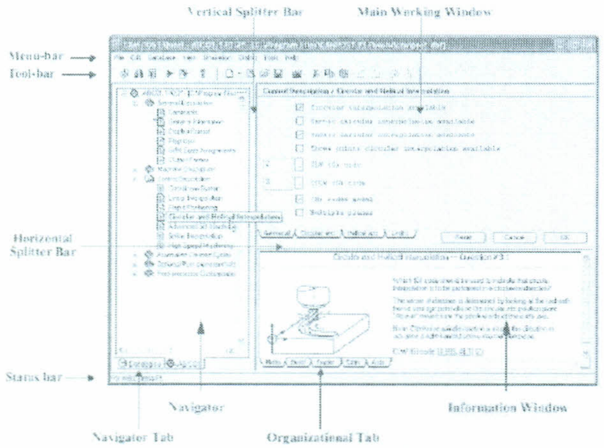

Fig 2: QUEST interface layout

The machine description has information related to the operation of machine, axis positioning limits and resolutions. Input of the pivot distance is one of the main parameter as shown in Fig 3.

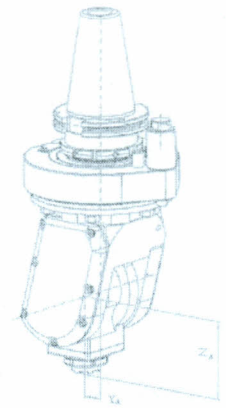

Fig 3: Pivot Length details of Indexing head

For A and C axis tilt there is a certain distance between the pivot point (centre of rotation) and the tool tip. This is called Pivot Length. For a Head moving CNC machining center, the length of the tool will also decide the pivot length. This has to be incorporated in CAM-POST to generate the postprocessor.

The optional post processor word is used to tailor the post processor vocabulary to the actual machine application. Functions such as spindle and tool control, coolant control, etc., are incorporated here.

This completes the creation of the customized post processor on QUEST, which is stored as a database.

GENER uses this information about CNC machine and its controller from the QUEST database to convert the points and vectors of cutter location data into control codes. Fig.4 shows the block diagram for workflow between QUEST and GENER.

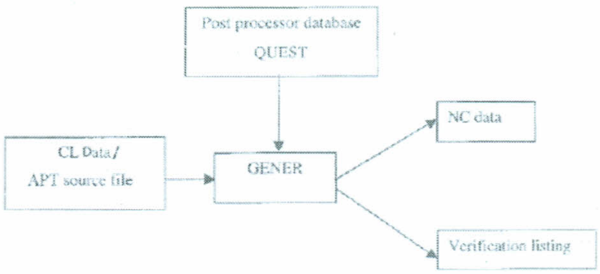

Fig 4: Block diagram of QUEST and GENER

The principle input for GENER is Cutter Location data (CL Data) or APT source file from CAM systems. The closed bevel angles are studied on the CAD model and optimal A and C values are obtained. These values are reflected in the APT output from the CAD/CAM software, which forms the input for the developed post processor. The GENER then post processes this APT/CL file for any CNC machine, which is defined in the QUEST database. GENER outputs the CNC part program and verification listing which can be used to check for errors. This verification listing contains a formatted summary of CNC programs. It lists the actual CNC control commands, machining time, file length, axes summary and diagnostic summaries. The NC output gives the A and C values which are then set manually on the tilting head attachment, there by A and C are Positioned.

The customized Postprocessor built using CAMPOST® V17 software allows special features like NURBS codes, High speed machining output functionalities to optimize the machining time based on the Machine acceleration, tool path and feed rate and Block transfer rates and Automated canned cycle functions of FANUC Series 21i-MB® controller.

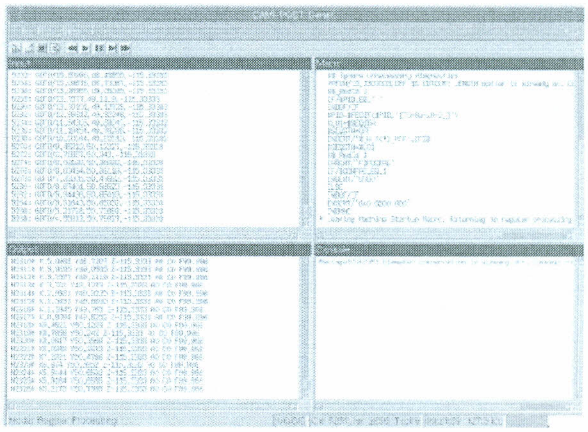

Fig 6: GENER Post Processing results

2. Validation of the Postprocessor

A typical aircraft component, using both three axes and positional five axes machining as, shown in Fig.5, was considered to validate the dedicated postprocessor.

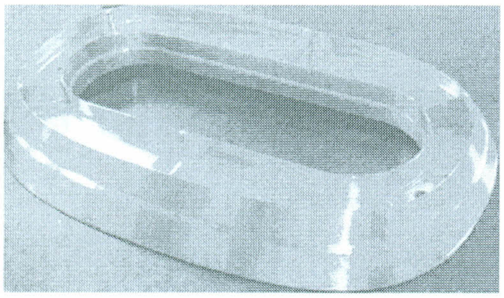

Fig 5: A typical aircraft component containing closed wall machining.

The CATIA V5 R17® advanced manufacturing module was used to generate the APT source code. This APT source code is input to the GENER to obtain the post processed output file, which incorporates the X, Y, Z, A and C axes traverse information, as shown in Fig. 6.

3.1 Virtual Validation

The validation methodology involved simulating the postprocessor output by using the VERICUT® software.

A three axes machining center with universal indexing head replicating the actual machine described earlier was constructed as shown in Fig.7, incorporating the machine specifications which included the pivot length of 25.1mm (Y offset value) and 79mm (Z offset value) in the machine component tree.

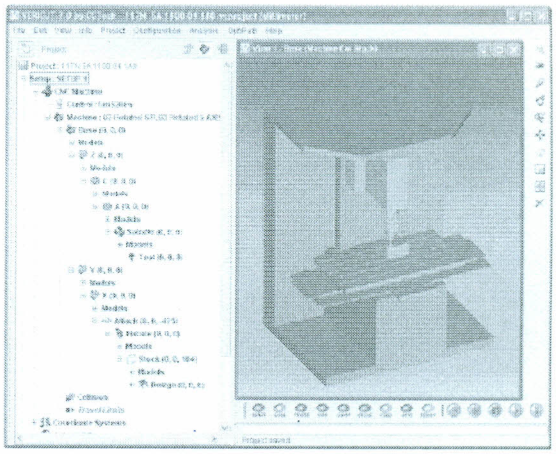

Fig 7: Virtual Machining Center constructed in VERICUT® Software

After completion of the configuration, the cutting action using the CNC code was performed, as shown in Fig. 8 and the virtual machined part was compared against the design model and was found to have no gouging or excess material and was within the predefined tolerance. This demonstrated that the performance of the developed post processor was very satisfactory and reliable.

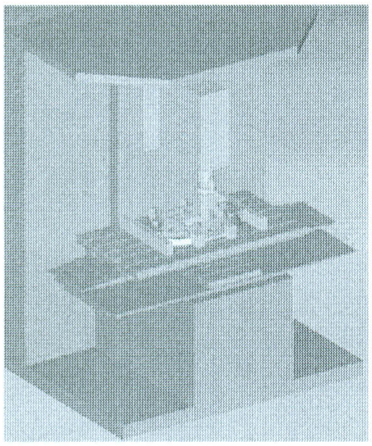

Fig 8: Machining Simulation in VERICUT®

3.2 Machine Validation

The closed bevel angles are studied on the CAD model and optimal A and C values are obtained and CAM Programing is done and then A and C angles are set manually on the tilting head attachment to Position the Tool.

An actual machining was then carried on the designated three axes Vertical Machining Center. The component was machined wherein the operations included both three axes and positional five axes machining. The positional five axes machining operation involved machining of the component as shown in Fig. 9.

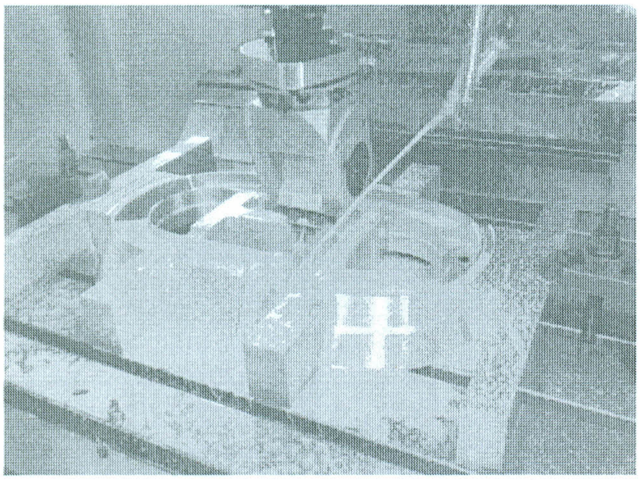

Fig 9: Positional five axis machining of a typical aircraft component having closed walls machined on three axes CNC Vertical Machining Center using the angular head.

The part after manufacturing was subjected to inspection on a Coordinate Measuring Machine (CMM). The dimensional deviations at a typical section are shown on Table 1. The machining deviation varied from 0.010 mm to 0.034 mm clearly proving the efficiency of the dedicated post processor in manufacturing of components involving positional five axes machining and are well within the standards [6].

Table 1: Results of Inspection

Sl. No	X(mm)	Y(mm)	Z(mm)	DEVIATION (mm)
1	51.436	40.912	55.078	0.02
2	113.435	30.079	55.078	0.03
3	107.827	-23.755	55.078	0.02
4	51.293	-42.755	55.078	0.015
5	99.488	-83.421	55.078	0.04
6	162.942	-81.811	50.957	0.01
7	162.942	-163.551	50.957	0.015
8	265.775	-178.591	50.957	0.025
9	262.775	-85.118	50.957	0.034
10	305.24	-124.877	50.957	0.025
11	306.427	-85.148	51.586	0.015
12	360.427	-180.509	51.586	0.011
13	514.298	-158.425	51.586	0.01

4. Conclusion

In this work, a customized post processor for a three axes machining center coupled with the angular indexing head using FANUC Series 21i-MB® controller was developed successfully by application of CAMPOST® post processor software as the base module. This work took into consideration all the parameters of the native machining center which included important parameters like high speed cycle machining facility and taking into consideration the look-ahead features and cutting parameters along with features of indexing head to facilitate and enhance the surface finish parameters which is of prime importance in manufacturing of aircraft components.

The Post processor also exploited the

functionalities of FANUC Series 21i-MB® controller, thereby enabling a highly optimized usage of the machine-controller combination. Further this software was independently evaluated by carrying out a five axes machining of an aircraft component and the APT source data was post processed by using the customized post processor. The output so generated was evaluated using the VERICUT® software wherein the entire machining kinematics was built and the post processed CNC codes were run, virtually machining the component. This part was further inspected and validated against the CAD part which fully satisfied the effectiveness of the post processor developed during this work. The actual machining of a typical aircraft component with closed walls was done, followed by inspection on a Coordinate Measuring Machine (CMM) which yielded the results confirming the efficiency and reliability of the developed dedicated post processor.

5. Acknowledgement

The authors are very thankful to Sri. Pradeep.M.S, Senior Technical Officer 'C' and Sri. Naresh.K.R, Senior Technical Assistant, APMF, C-CADD, NAL for their technical support.

6. References

1. Xingui Guo, Yadong Liu, Kazuo Yamazaki, Keizo Kashihara, Makoto Fujishima, *A study of a universal NC program processor for a CNC system*, International Journal of Advanced Manufacturing Technologies (2008) 36: 738-745

2. FANUC Series 21i-MB® Technical Manual

3. DAHLIH Technical Manual

4.CAMPOST® V17 User Manual, URL: http://www.icam.com

5. VERICUT® User Manual, URL: http://www.cgtech.com

6. National Aerospace Process (NAP) Specification on General Manufacturing Tolerances, Document Number: NAL/NAP/016, Issue B, Revision NIL, 2011